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Cpk:
Indispensable index or misleading measure?

By Steve Daum

What is capability analysis and why do it?

Capability analysis is a set of calculations used to assess whether a system is able to meet a set of requirements. Customers, engineers, or managers usually set the requirements, which can be specifications, goals, aims, or standards.

The primary reason for doing a capability analysis is to answer the question: Can we meet customer requirements? To be more specific: *Can our system produce consistently within tolerances required by the customer now and in the future?*

Capability analysis involves two entities: 1) the producer and 2) the consumer. The consumer sets the requirements and the producer must be able to meet the requirements.

Capability analysis can be used as structured communication that flows between producers and consumers. This communication happens up and down the supply chain and is useful in different contexts. For example, it can be useful when a manufacturer is considering the purchase of a new machine. It can be useful when a producer is working through the Production Part Approval Process (PPAP). It can be useful during contract and pricing negotiations between a producer and a potential customer.

Since capability analysis plays this important role in the supply chain, the language of a capability analysis must be consistent and agreed to among interested parties. For this, guidance is provided in standards such as IATF 16949 and in publications such as those produced by the Automotive Industry Action Group (AIAG). The primary statistics resulting from capability analysis are the capability index **(Cpk)** and the performance index **(Ppk)**.

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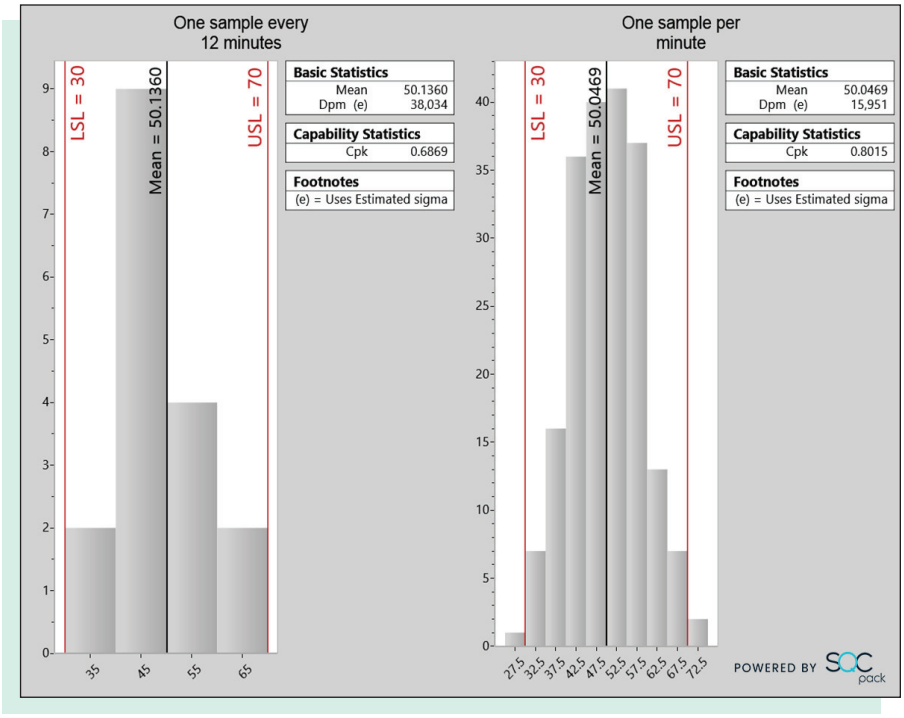
This paper focuses mainly on Cpk. For more information on the differences between the two indices and when to use each, see http://www.pqsystems.com/qualityadvisor/DataAnalysisTools/capability_cpk_or_ppk_whichshouldyouuse.php.

Capability analysis can add value in the supply chain, if you proceed with caution. Here's how to make its use more effective:

I. Understand Capability Analysis

Mark Twain said "*Facts are stubborn things, but statistics are pliable.*" Both when consuming and when producing a Cpk result, be aware that Cpk is easily manipulated.

Altering the sample size, the sample frequency, or the numerical precision of the data values can have an impact on a Cpk result. Sampling too frequently, for example, will artificially reduce the range values and cause Cpk values to appear high.



As an example, compare the Cpk on these two histograms. Both are based on the same stream of data coming from a process. The histogram on the left takes a sample every 12 minutes. The one on the right takes a sample every minute. As you can see, the histogram on the right results in a higher Cpk. This would be more appealing to the *consumer* but the *producer* has not made a real improvement.

Whether you are the producer or the customer, if you are using capability analysis for decision making in your organization, you must fully understand its use. Computing Cpk is not difficult. Understanding whether or not the value is a reasonable representation of the underlying process, however, is critical to using capability analysis effectively.

There are many resources for learning the mechanics and formulas for doing a capability analysis. Here is one example: http://www.pqsystems.com/qualityadvisor/DataAnalysisTools/capability_analysis.php

Recommended resources for enhancing your understanding of capability analysis include:

Process Evaluation Handbook, Donald J. Wheeler
Beyond Capability Confusion, Donald J. Wheeler
SPC Quickstart Guide, AIAG
Statistical Process Control, AIAG

Once your understanding of capability analysis has been developed, ongoing practice is required to keep the knowledge current and to pass it on to others involved in quality management and monitoring.

II. Understand what your customers want/need

Once you have a working knowledge of capability analysis, you need to communicate with your customers about their requirements. Typically, the customer will have requirements for many different characteristics or metrics. However, not all of these will be equally important. Some may have little or no effect on the quality of the final product; others may have serious impacts.

Dr. Donald J. Wheeler, in *The Process Evaluation Handbook*, defines a critical characteristic as one that is both important to your customer and is also more difficult to produce consistently within the specifications.[1]

An important communication between you and your customer involves agreement on which characteristics are so critical that capability analysis is a requirement. Furthermore, what level of Cpk or Ppk index is required? Since there is a cost to doing capability analysis, it is important that blanket statements such as *all characteristics must consistently product a Cpk of 1.5* are carefully considered. We have seen products that have hundreds of characteristics with tolerances specified. It is rarely the case that every one of these characteristics is truly critical.

Once the characteristics requiring capability analysis are identified, the next questions are how often the analysis should be done and how the results will be communicated. There are many options here. The important result is communication – discussion and agreement between producer and customer.

III. Study what your current system can do (your capability)

For each metric where the customer has a specific requirement, you must conduct a capability analysis to see if you are currently meeting these needs. When doing this analysis, it is important to remember that control must come before capability. In other words, assess your process for statistical process control first. If the system is not predictable (in statistical control, reflected on a control chart) you must address these problems before doing a capability analysis. Although SPC is an acronym for statistical process control, it can also serve as a reminder for **Stability**, **Predictability**, and then **Capability**.

In assessing process control, it is important to remember that specifications are not the same as control limits. As Dr. Wheeler states, "Specifications are the voice of the customer, not the voice of the process." Control limits are calculated from process data. Dr. W. Edwards Deming made this clear in *The New Economics* when he stated ". . . there is no logical connection between control limits and specifications" (p. 178).[2]

A control chart with limits calculated from the data will reveal whether or not the process is statistically stable.

IV. Compare the customer needs with your capability

You know what the customer needs and you know what you can do. In this step you compare these numbers.

If you meet the customer needs (Cpk high enough):

This is the good case. Continue doing business with this customer. Implement an ongoing program for evaluating capability and ensuring that you continue to meet this customer's needs. But don't stop there. Consider that your customer's specifications simply draw a line in the sand of what's acceptable and what's not.

A focus on tolerances and capability analysis can lead to *category* thinking. For example, defining something as being either *good* or *bad* is category thinking. Category thinking can ease decision making, but sometimes a more subtle approach is needed.

Instead of thinking that *within specs is good; outside of specs is bad*, the Taguchi loss function encourages *continuous thinking*. For example, a measurement exactly on target is good. Any measurement moving above or below the target incurs cost. The further from target, the higher the cost, where cost is considered broadly as *cost to society*. You may be meeting your customer requirements but are you still reducing overall costs?

Dr. W. Edwards Deming wrote "The most important use of a loss function is to help us change from a world of specifications (meet specifications) to continual reduction of variation about the target, through improvement of processes" (p. 217, *The New Economics*).[2] Consider what the variation is costing your business, and work to reduce the variation where it makes good business sense.

If you do not meet the needs (Cpk is too low):

Consider this scenario: You are a producer. You have a potential customer who requires a Cpk value on a critical metric of at least **2.3**. You conduct a capability analysis. The Cpk you calculate is **2.1**. The question is: **How do you make your Cpk higher?** Once you have eliminated possible measurement errors and math errors, you have four options:

1. Improve the center of your process so that it is closer to the center of the tolerance range.
2. Reduce the variation around the center by making system changes, which might include:
    a. Improve the machinery
    b. Purchase new machinery
    c. Improve the training of operators
    d. Improve the standard work procedures
    e. Improve input materials into your process

Options 1 and 2 fall in line with a continuous improvement approach to quality management. The problem is that they do not consider the financial point of view. How much will it cost to improve the centering? How much will it cost to reduce the variation? Dr. Deming famously said *improve constantly and forever* but he did not say to go out of business doing it. In fact, he stated, "The aim proposed here for any organization is for everybody to gain - stockholders, employees, suppliers, customers, community, and the environment – over the long term" (The Deming Institute, quotes.deming.org).

The final two methods involve the customer.

3. Widen the tolerances

Making the tolerances wider is part of the communication between producer and consumer. Are the tolerances critically important to the functioning and quality of the product? Sometimes the answer will be yes, and the consumer will insist on the tolerances.

However, it is possible that a design engineer has applied some *rule of thumb* tolerances while making the drawing and these were never really shown to be essential. Often, standard contract language may be in play that is not relevant to the current situation. When you do the math, you will see that leaving your data alone and **only** making the tolerances wider **will increase your Cpk** – if the customer agrees.

4. Agree that it is not a good fit

Imagine that you are daydreaming while you wait in line at a fast food drive through. When you pull up to the speaker, before fully returning from your daydream, you place an order like this:

> "I'll have a petite filet mignon, butterflied and cooked medium rare. On the side, I'd like a wild mushroom risotto. Additionally, I'd like a fresh salad of mixed greens tossed in a light balsamic vinaigrette dressing."

The McDonalds worker hearing this order will know, without doing any analysis, that the organization is not capable of meeting your requirements. There is no question of improving so that they can meet your needs. If these are truly your needs, you just have to accept the fact that you need a different supplier. In the supply chain world, this scenario can play out. The communication between supplier and customer around the topic of capability analysis may result in an agreement not to do business. No one likes to lose business, but walking away may be a win for both parties in the long run when there is not a good match between the capabilities and the needs.

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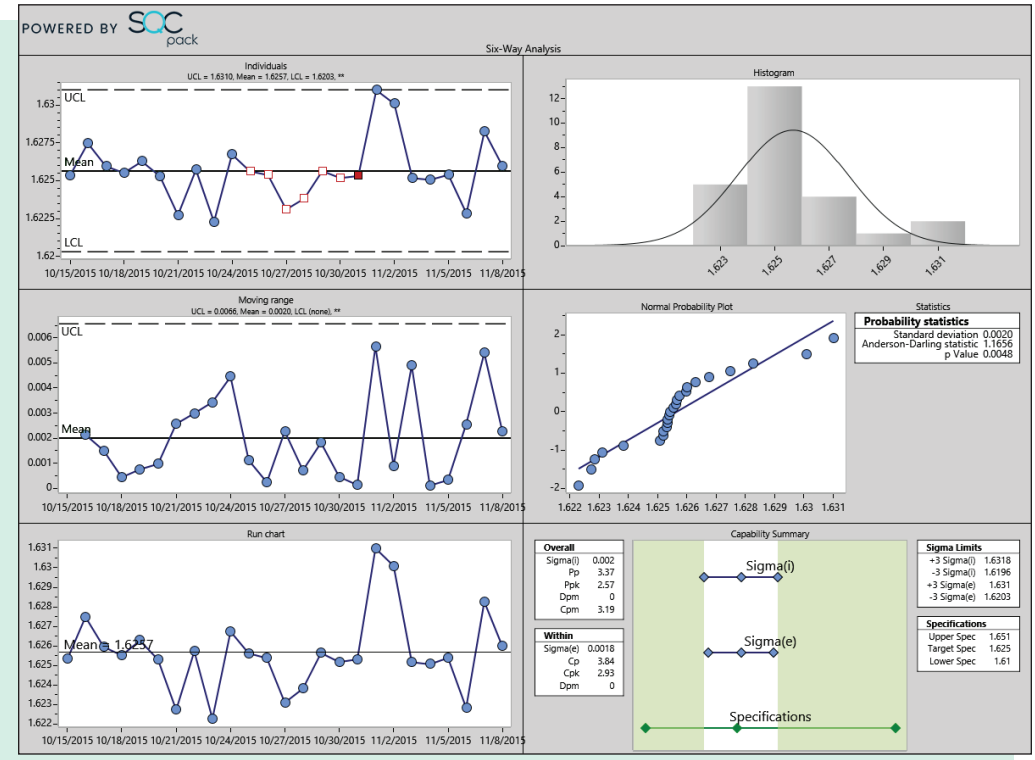
V. Define ongoing monitoring for system changes

Once you are fluent in both performing capability analysis and communicating its results, it is important that your team implement ongoing procedures for paying attention to how well you are doing. This might include weekly, monthly, or quarterly reviews of capability analysis on all key customer metrics.

In a similar fashion, capability analysis should be seen as one of many tools that contribute to understanding and improving quality. A popular summary, known as **Six-Way Analysis**,™ is a good way to show not only capability analysis but also statistical control, trends, and the distribution of your data in a single-page visual – that is easy to consume. The various attributes of the process of Gap Dimension A come together in this example for a more complete evaluation of the process:



Summary

An important point when thinking about a Cpk result is that it is just one statistic. It is designed to answer a specific question, and it does this well. By analogy, think about the blood pressure reading taken at your last doctor visit. The reading may have been quite good; however, the doctor considered many other factors before giving you a clean bill of health.

Capability analysis plays an important role up and down the supply chain. Used wisely, it can be one measure to demonstrate a system's ability to meet its numerical requirements. Used over time, it can be an excellent tool to demonstrate the extent of an improvement made to a process. But just as you would not run your entire business on your inventory turnover ratio alone, don't run your entire manufacturing operation solely on capability analysis.

Footnotes:

[1] *The Process Evaluation Handbook*, Wheeler, Donald J.

[2] *The New Economics 2nd Edition*, Deming, W. Edwards.

Other sources:

Practical Tools for Continuous Improvement, Volume 1, Cleary, Michael J. and Graham, Jacqueline D.

Understanding Variation: The Key to Managing Chaos, Wheeler, Donald J.

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ABOUT THE AUTHOR

Steve Daum is Director of Software Engineering for PQ Systems. He has more than 30 years of experience with statistical process control, control charts, and control charting software. Steve has published papers in a variety of professional journals and has led multiple seminars and presented on statistical process control and issues related to quality to a variety of audiences in the U.S., England, and South Africa. To learn more about PQ Systems' software applications SQCpack and GAGEpack, visit www.pqsystems.com.